REDACTED VERSION

APPENDIX NOT INCLUDED

Soil Feasibility Study Report
Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma
EPA Identification No. OK0001010917

Remedial Investigation/Feasibility Study
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LIST OF ACRONYMS AND ABBREVIATIONS

95 UCLM	95 Upper confidence limit of the mean
μg/L	Microgram(s) per liter
ARAR	Applicable or relevant and appropriate requirement
bgs	Below ground surface
BaP	Benzo(a)pyrene
BRAPF	Baseline Risk Assessment Problem Formulation
CalEPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm/s	Centimeter per second
COC	Chemical of concern
COPEC	Constituent of potential ecological concern
COPC	Chemical of potential concern
CSM	Conceptual site model
cy	Cubic yard(s)
EA	EA Engineering, Science, and Technology, Inc., PBC
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ERA	Ecological Risk Assessment
FS	Feasibility Study
ft	Foot (feet)
GRA	General Response Action
HDPE	High density polyethylene
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard quotient
IC	Institutional control
IEUBK	Integrated Exposure Uptake Biokinetic
ISB	In situ enhanced bioremediation
ISCO	In situ chemical oxidation
ISS	In situ stabilization and solidification
LNAPL	Light non-aqueous phase liquid
LTU	Land treatment units
LUC	Land use control

MCL	Maximum contaminant level
mg/kg	Milligram(s) per kilogram
mil	Milli-inch

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	No further action
NPL	National Priorities List
OAC	Oklahoma Administrative Code
ODEQ	Oklahoma Department of Environmental Quality
OSWER	Office of Solid Waste and Emergency Response
PAH	Polycyclic aromatic hydrocarbon
PEL	Probable effects level
PRG	Preliminary remediation goal
RA	Remedial Alternatives
RAC	Remedial Action Contract
RACER	Remedial Action Cost Engineering and Requirements
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial investigation
ROD	Record of Decision
RSL	Regional screening level
sf	Square foot
Site	Wilcox Oil Superfund Site
SLERA	Screening Level Ecological Risk Assessment
SVOC	Semivolatile organic compound
TBC	To be considered
TMV	Toxicity, mobility, or volume
TRV	Toxicity reference value
VOC	Volatile organic compound
XRF	X-ray fluorescence

1. INTRODUCTION

EA Engineering, Science, and Technology, Inc., PBC (EA) has prepared this Feasibility Study (FS) Report for the U.S. Environmental Protection Agency (EPA) for the Wilcox Oil Company Superfund Site (site) in Bristow, Creek County, Oklahoma (Figure 1-1) under Remedial Action Contract (RAC) Number EP-W-06-004 and Task Order 0128-RICO-06GG. This report addresses contamination in soils at the site. The groundwater contamination is in investigation and will be addressed in a separate report.

This revised FS Report, Revision 01 incorporates the comments from EPA and Oklahoma Department of Environmental Quality (ODEQ) on the FS Report, Revision 00 which was submitted on 8 January 2021. The responses to comments on the FS Report, Revision 00 are provided in Appendix A.

EA prepared this report based on the Remedial Investigation (RI) Report, Revision 02 (EA 2020a), Human Health Risk Assessment (HHRA), Revision 03 (EA 2020b), and Screening Level Ecological Risk Assessment (SLERA), Revision 01 (EA 2020c), and in accordance with regulations and guidance documents that include, but are not limited to, the following:

- National Oil and Hazardous Substance Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300

- *Guidance for Conducting Remedial Investigation and Feasibility Studies under Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), Office of Solid Waste and Emergency Response [OSWER] Directive 9355.3-01 (EPA 1988)

This FS was drafted to generally follow the framework of EPA Guidance for Conducting RIs and FS under CERCLA (EPA 1988).

1.1 PURPOSE AND SCOPE

The purpose of this report is to support a selection of remedies for the soil contamination at the site by:

- Proposing the remedial action objectives (RAOs)

- Defining specific preliminary remediation goals (PRGs)

- Developing and analyzing a range of remedial alternatives (RAs).

1.2 REPORT ORGANIZATION

This FS is divided into the following chapters:

- ***Chapter 1, Introduction***—Presents the purpose of this FS Report and its organization.
- ***Chapter 2, Site Description and Background***—Provides a summary of the site history, results of RI, HHRAs and ecological risk assessments (ERAs), site conceptual site model, and potential groundwater remedial technologies.
- ***Chapter 3, Groundwater Data Gap and Potential Technologies***—Discusses existing data gap for groundwater and technologies that may be considered for future groundwater remediation.
- ***Chapter 4, Remedial Action Objectives***—Defines RAOs, proposes PRGs, and identifies the applicable or relevant and appropriate requirements (ARARs) for the site.
- ***Chapter 5, Development and Screening of Technologies***—Identifies and screens various potential remedial technologies and options that may be used to address contaminant of concern (COC)-impacted soil.
- ***Chapter 6, Development of Remedial Alternatives***—Presents the remedial alternatives and the components of each alternative.
- ***Chapter 7, Evaluation of Remedial Alternatives***—Presents the detailed analysis and comparative analysis of the alternatives.
- ***Chapter 8, References***—Provides the list of references used in this report.

2. SITE DESCRIPTION AND BACKGROUND

2.1 SITE DESCRIPTION

The Wilcox Oil Company site is an abandoned and demolished oil refinery and associated tank farm located north of Bristow, Creek County, Oklahoma (Figure 1-1). It is situated by Route 66 to the west; a residential area and Turner Turnpike to the north and northwest; Sand Creek to the west and southwest; and residential, agricultural, and wooded areas to the east and south. The approximate geographic coordinates for the site are 35°50’31” North latitude and 96°23’02” West longitude (EA 2020a). The site spans approximately 140 to 150 acres and has been divided into five (5) major former operational areas (Figure 2-1):

- The Wilcox Process Area
- The Lorraine Process Area
- The East Tank Farm
- The North Tank Farm, and
- The Loading Dock Area.

Previous activities associated with the facility operations had caused site contamination. Some refinery waste is still present at the site but is fenced and secured to deter trespassing and potential contact with the waste.

The Wilcox Process Area is approximately 26 acres in size and is fenced. Most of the equipment and storage tanks used in the past were auctioned and/or salvaged by private land owners; any remaining structures are in ruins. Four aboveground storage tanks, a number of discarded drums and pieces of scrap iron and piping remain at the site. A former lead additive area is barren and located at the southwest portion of the Wilcox Process Area. There are multiple areas of stressed vegetation, barren soil, and visible black tarry waste of a hydrocarbon nature. Buildings in the northern and eastern parts of the former refinery were used as residences and are therefore considered as such, although they are currently vacant. An intermittent creek (West Tributary) flows southward across the eastern portion of the refinery process area through a small pond in the southeast corner of the Wilcox Process Area into Sand Creek. Hydrocarbon waste has also been observed in several drainage channels that empty into Sand Creek.

The Lorraine Process Area spans approximately 8 acres and is to the west of the Wilcox Process Area across the railroad tracks. No refinery structures remain in the area. The First Assembly of God Church (currently vacant), a playground, and a vacant residence (parsonage) are located in this area. Sand Creek borders the western boundary of the area. A drainage feature is located near the northwestern corner of the former process area that drains south into Sand Creek. Similar to the Wilcox Process Area, there are multiple areas of stressed vegetation, barren soil, and visible, black tarry waste present in the area.

The East Tank Farm is located to the east of the Wilcox Process Area and spans approximately 80 acres. The area includes pits, ponds, and a number of circular berms that surrounded former tank locations. All of the former crude oil storage tanks have been removed; however, remnants of the former tank locations remain visible. It is not known if underground piping associated with the tanks remains in place or was removed. Many of the berms surrounding the pits, ponds, and former tanks have been breached or leveled. The three residential properties, which are occupied, are located on or directly next to former tank locations in the East Tank Farm. There are multiple areas of stressed vegetation, barren soil, and visible black tarry waste. The East Tributary is located along the eastern boundary of the East Tank Farm and perennially flows south through a series of ponds to Sand Creek.

Magellan Midstream Partners, LP operates a pumping station in the north-central portion of the East Tank Farm Area, as well as an active pipeline that transects the East Tank Farm, Loading Dock, and North Tank Farm Areas from the southeast to the northwest. Magellan Midstream Partners, LP pumped several different petroleum products through the active pipeline, including kerosene, gasoline, jet fuel, and diesel.

The North Tank Farm is located north of Refinery Road, also referred to as E0810, and west of the railroad tracks and spans approximately 20 acres. All of the tanks and other structures that were used to support Lorraine Refinery to the south have been removed. An occupied residence is located in the center of the North Tank Farm. There are areas of stressed vegetation, and visible black tarry waste is present.

The Loading Dock Area spans approximately 7 acres and is located north of the Wilcox Process Area and east of the North Tank Farm and railroad tracks. The Loading Dock Area was used for loading and unloading product by rail. There are multiple areas of stressed vegetation, barren soil, and visible black tarry waste of a hydrocarbon nature, similar to the rest of site.

2.2 SITE HISTORY

The property was used for oil refinery operations from 1915 until November 1963. A modern oil refinery plant was constructed in 1929. The upgraded facility consisted of a skimming plant, cracking unit, and re-distillation battery with a vapor recovery system and treatment equipment. The Wilcox Oil Company expanded when it acquired the Lorraine Refinery in 1937 and sold the property to a private individual in 1963. Most of the equipment and storage tanks were auctioned or salvaged for scrap metal by the new property owners. Wilcox Oil Company currently no longer operates in Oklahoma. Based on information from the Oklahoma Secretary of States' office, the company merged with Tenneco Oil Company in 1967. On 24 May 2013, EPA proposed the site to the National Priorities List (NPL). On 12 December 2013, the site officially became a Federal Superfund site (EPA Identification No. OK0001010917), when it was added to the NPL.

2.2.1 Previous Investigation and Removal Activities

The EPA and ODEQ have conducted multiple investigations at the site since 1994. The details of the investigations can be found in the individual documents listed in the RI Report (EA 2020a).

In September and October 2017, EPA conducted a removal action and removed oily sludge and contaminated soils from a residential property at the site. Approximately 1,329 tons of oil impacted soils and sludge were removed and disposed offsite (Weston 2017). The area was backfilled with clean soil and graded and reseeded.

2.2.2 Source Control Record of Decision Summary

A Source Control Record of Decision (ROD) Summary was issued in September 2018. The ROD addresses the refinery tank waste and the lead additive area source materials through excavation, treatment, and offsite disposal (EPA 2018). This source control action is an early/interim action that does not constitute the final remedy for the site; therefore, any subsequent actions to address the remaining risks and threats posed by the site conditions will be documented in a final site-wide decision document. This FS Report provides support for the site-wide decision document.

2.3 SURFACE FEATURES

The site topography slopes to the southwest and southeast with sandstone outcrops throughout. The railroad tracks run through the western portion of the site, and divides the North Tank Farm and Loading Dock Area; and Wilcox Process and Lorraine Process Areas. Several drainage features are present at the site. West Tributary, an intermittent stream, is located at the eastern side of the Wilcox Process Area; East Tributary, a perennial stream and five ponds are located at the East Tank Farm; and several drainage channels transect the property east of the railroad. All streams and channels flow to the south to Sand Creek (EA 2020a) at the southern and southwestern boundaries of the site. Sand Creek meanders approximately 3.5 miles south and east from the site until it merges with Little Deep Fork Creek.

A wetland survey was conducted in September 2016 and identified 4 wetland areas at the site (EA 2017) (Figure 2-2). Two wetlands are located in the Wilcox Process Area and one in the North and one in the East Tank Farms. Among the 4 wetlands, 3 are connected with Sand Creek, which are Wetland 2 in the Wilcox Process Area associated with West Tributary, Wetland 3 in North Tank Farm with vegetated drainage ditches to Sand Creek, and Wetland 4 in East Tank Farm along the East Tributary. Wetland 1 in the Wilcox Process Area is not directly connected with any tributaries and appears to obtain water from surficial runoff (EA 2017).

There are seven residential buildings/houses at the site, one in the North Tank Farm, one in the Lorraine Process Area, two in the Wilcox Process Area, and three in the East Tank Farm. The houses in the Lorraine Process Area and Wilcox Process Area are currently unoccupied while the rest of the houses in the other areas are occupied. A church and a playground are located in the Lorraine Process Area.

Staining of the soil, black tarry waste, stressed vegetation, and barren areas are present throughout the site. Storage tanks, refinery-related debris, and piping still remain in the Wilcox Process Area, while evidence remains of former tank berms that were cut and leveled in the East Tank Farm (EA 2020a).

2.4 FUTURE LAND AND GROUNDWATER USE

Residential use is expected to continue for all residential properties in the East Tank Farm, Lorraine Process Area, and Wilcox Process Area. A large portion of the East Tank Farm, currently used for grazing, may be used as a residential property in the future based on discussions with the current landowner. The residential area in the Wilcox Process Area includes the house, storage tanks, and driveway.

The remaining portion of the Wilcox Process Area consists of the remaining refinery structures and features, which is currently unused. It is likely that the anticipated reuse for this property would be industrial.

Residential properties associated with the North Tank Farm, the Lorraine Process Area, and the Wilcox Process Area are currently on public water supply, which is supplied by 4 wells approximately 400 feet (ft) deep in the Vamoose-Ada aquifer. Residences located on or near the East Tank Farm obtain water from individual groundwater wells set in the Barnsdall Formation, which is much shallower than the Vamoose-Ada aquifer (EA 2020a).

2.5 GEOLOGY AND HYDROGEOLOGY

The site is situated on the Pennsylvanian-aged Barnsdall Formation, which is composed of fine-grained sandstone overlain by shale. Thickness ranges from 80 to 200 ft (ODEQ 2008) but is approximately 200 ft thick at the site. Sandstone outcrops of the Barnsdall Formation are common throughout the site. Southeast of the former refinery, the underlying Pennsylvanian-aged Wann Formation and underlying Iola Limestone are exposed. The Wann Formation varies in thickness from 40 to 180 ft and is comprised of shale and fine- to medium-grained sandstone. The Iola Limestone ranges in thickness from 15 to 20 ft and consists of a calcareous fine-grained sandstone and limestone with some shale.

Approximately 0.25 miles to the southeast of the former refinery, Quaternary-aged alluvial deposits associated with Sand Creek occur. These deposits consist of sand, silt, clay, and lenticular beds of gravel that overlie the older geologic units where these deposits exist. Thickness in these deposits ranges from 5 to 50 ft (25 ft average). Given that Sand Creek borders the site to the south, localized alluvium may be present (ODEQ 2009).

The Barnsdall Formation is a bedrock aquifer and is not considered a principal groundwater resource by the Oklahoma State Department of Health (ODEQ 1994). It consists of massive-to-thin beds of coarse-to-fine grain sandstone, irregularly interbedded with sandy to silty shale. Under the Barnsdall Formation lies the Vamoose-Ada aquifer in close proximity to the west of the site. The Vamoose-Ada aquifer is an important central Oklahoma regional drinking water aquifer (E&E 1999), which is the source for the public water supply in the area.

The shallowest regional water-bearing formation in the upper part of the Barnsdall Formation is unconfined and is overlain by the unconfined shallow perched groundwater zone. The Barnsdall

Formation potentially receives groundwater recharge from precipitation and infiltration from the perched groundwater zones. Depths to seasonal perched groundwater zones are less than 10 ft and depth to groundwater ranged from 4.84 to 15.97 ft below ground surface (bgs) in the groundwater monitoring wells installed at the Lorraine and Wilcox Process Areas. The shallowest regional water-bearing formation (associated with the Barnsdall Formation) is reportedly less than 25 ft bgs (ODEQ 1994). The primary groundwater flow path for the perched groundwater zone is to the south towards Sand Creek. Figure 2-3 present a potentiometric surface map based on 2018 data. The local gradient averages approximately 0.021 foot per foot across this portion of the site.

2.6 REMEDIAL INVESTIGATION RESULT SUMMARY

The RI was conducted during a series of eight field events that occurred from August 2016 through December 2018. A total of 473 surface soil samples, 355 subsurface soil samples, 44 sediment samples, 56 surface water samples, and 35 groundwater samples were collected during the sampling events. Additional groundwater sampling was performed in August 2020 as part of a separate data gap investigation, and Appendix B provides details of the data gap investigation (Appendix B). A geophysical survey, a Rapid Optical Scanning Tool laser-induced fluorescence survey, and a field-portable X-ray fluorescence (XRF) survey across portions of the Wilcox Process Area, the Lorraine Process Area, and the East Tank Farm were conducted for the 2016 Trip Report. A passive soil gas survey and vapor intrusion sampling were also conducted in 2016. In addition, waste characterization sampling was conducted at 16 locations as well as at excavated test pits where waste was visibly present (EA 2020a).

The RI results indicated that the site soil, sediment, surface water, and groundwater have been impacted by the refinery operations. The chemicals of potential concerns (COPCs) include:

- Soil, sediment, and groundwater: Polycyclic aromatic hydrocarbon (PAHs)/semivolatile organic compound (SVOCs), volatile organic compound (VOCs), and metals

- Surface water: PAHs and metals.

Indoor air samples from existing buildings within the Lorraine Process Area and Wilcox Process Area revealed COPCs. However, sub-slab soil gas samples did not reveal any COPCs below these buildings. As a result, the indoor air COPCs are likely a result of indoor source areas and not vapor intrusion from groundwater. Therefore, vapor intrusion from groundwater into existing buildings at the site is not considered complete, and indoor air COPCs were not assessed in the HHRA.

The HHRA and the SLERA were conducted to evaluate the COPCs. This section summarizes the site RI overall results and risk assessment results. The RI Report (EA 2020a) provides more details of the investigation.

2.6.1 Waste Materials

Most of the waste at the site is relatively shallow. The waste materials encountered consisted primarily of surficial, crusted tar-like materials, in some cases flowable tar-like material, black stained soil, and oily soil.

The waste materials not identified in the Source Control ROD (EPA 2018) are included in this FS. Soil within the lead additive area that has lead concentrations exceeding 800 milligrams per kilogram (mg/kg) will be removed during the source control remedial action. The areas that are addressed under the Source Control ROD are presented in Figure 2-4. Since the remaining materials and impacted soil may still post unacceptable levels of risks under the current and future land use, they could be sampled for risk evaluation and characterization for disposal.

2.6.2 Soil

The HHRA identified that there are human health concerns under current and future land use for exposure to the site COCs, benzo(a)pyrene (BaP) and lead. The HHRA section of this FS Report describes details of the risk assessment that identified the COCs to be addressed in this FS.

The SLERA found that the metals (chromium, copper, lead, vanadium, and zinc) in the surface soil pose risks to terrestrial plants in the Wilcox Process and Lorraine Process Areas. Metals, including chromium, manganese, and vanadium, in the surface soil in the North and East Tank Farms and Loading Dock Area also pose risks to terrestrial plants.

Surface soil contains concentrations of chromium, copper, mercury, isopropylbenene and xylenes, posing risks to soil invertebrates at the site. Lead has been found in surface soil in the two process areas, posing risks to terrestrial mammals. Surface soil lead, copper, and vanadium pose risks to terrestrial birds as well.

The following summarizes the areas where the soil was addressed in this FS based in the RI and HHRA.

- Wilcox Process Area: This area is divided into two areas based on the land use; one is a residential area and the other area is an industrial area. The residential area is located in the northern Wilcox Process Area and includes a house, storage tanks, and a driveway (Figure 2-5). One sample location in the residential area exceeded the BaP PRG, and several other locations exceeded the lead residential PRG. The depth of the lead and BaP contamination is from 0-2 ft bgs. The exceedance area covers approximately 39,942 square feet (sf). Three XRF samples collected by EPA along West Tributary exceeded the soil residential lead PRG and will be addressed in this FS. These sediment samples were considered as soil in the HHRA, and the Sediment and Surface Water section of this FS Report provides the details of these three XRF samples.

  In the industrial area, six sample locations exceeded BaP PRGs, and multiple sample locations exceeded the lead industrial PRG (Figure 2-6). 2018 XRF data collected by

EPA is also included in this FS. The depth of the lead contamination is primarily from 0 to 2 ft bgs, with only one location that is from 2 to 6 ft bgs. The depth of BaP contamination is to 6 ft bgs at three locations, from 2 to 8 ft bgs at one location, from 2 to 13 ft bgs at one location, and from 0 to 2 ft bgs at one location.

- Lorraine Process Area: This area is considered for residential use and contains three locations with exceedances of BaP PRGs (Figure 2-5), among which two locations are isolated and therefore not considered in the quantity estimate. The BaP contamination depth is from 0 to 2 ft bgs and covers approximately 9,528 sf. There are also three areas with exceedances of lead PRGs (Figure 2-5). The depth of lead contamination is from 0 to 2 ft bgs, except at one location where the lead contamination is from 2 to 6 ft bgs. The lead exceedance areas cover a total of 46,985 sf.

- East Tank Farm: This area is also considered for residential use and contains three lead exceedance areas. The depth of lead contamination is from 0 to 2 ft bgs, and the three areas cover a total of 113,948 sf (Figure 2-5).

- North Tank Farm and Loading Dock Area: The soil in these two areas does not pose unacceptable risk based on the HHRA, therefore they are not carried forward in this FS.

2.6.3 Sediment and Surface Water

Based on the findings of the HHRA, there were no human health concerns for exposure to surface water and sediment within Sand Creek and its tributaries and onsite and nearby ponds that were sampled during the RI. XRF sediment samples were collected along the bank of West Tributary. During the HHRA, these sediment samples were evaluated as soil because the tributary is ephemeral and was dry when the samples were collected. The soil / sediment XRF data exceeded residential lead PRG for soil in three locations in the Wilcox Process Area (Figure 2-5). The exceedance area will be addressed in this FS.

The SLERA found that cadmium, lead and BAP in the surface water of the ponds may pose risks to aquatic organisms. Total PAHs and manganese in sediment and surface water in Sand Creek and its tributaries also pose risks to aquatic and benthic organisms.

2.6.4 Groundwater

The HHRA identified potential risks exist for exposure to the groundwater associated with the perched shallow groundwater unit, assuming domestic use, in the Wilcox Process Area and Lorraine Process Area.

Due to the limited groundwater data available, a data gap investigation was determined to be required to evaluate the site groundwater conditions. Therefore, additional groundwater investigation was conducted in August 2020. Temporary wells were installed and groundwater samples were collected at old and new monitoring wells, temporary wells, and water wells. Aquifer tests were performed at existing monitoring wells to evaluate site-specific hydraulic parameters. Groundwater levels were gauged and a survey of Sand Creek was conducted to evaluate potential communication between groundwater and the creek. The data gap investigation results are summarized in the Technical Memorandum on Data Gap Investigation (Appendix B).

Light non-aqueous phase liquid (LNAPL) was present in the soil cores at multiple locations in the Wilcox and Lorraine Process Areas during the temporary well installation in August 2020. Depths of the LNAPL ranged from 7 ft to 17 ft bgs and depths for sheens and soil staining associated with LNAPL went to 30 ft bgs (Appendix B). Although present in the soil cores, LNAPL was not observed in all of the temporary wells in the August 2020 sampling event. Existing well MW-4 in the Wilcox Process Area was the only well that contained measurable LNAPL in August 2020. Based on the RI Report (EA 2020a), MW-4 did not contain LNAPL in the 2018 sampling event although LNAPL was present in the soil cores from the well installation in the same year. In addition, during RI activities in 2016, approximately 6 ft of LNAPL was observed in GW-10 in the Lorraine Process Area and approximately 8 gallons of LNAPL was bailed from the well on 14 and 15 September 2016. But after one week of the bailing, 0.14 ft of LNAPL was observed in GW-10 on 22 September 2016. The well, which was plugged and abandoned in 2017 was located to the west of LPA-SB-17 and to the north of LPA-GW-01, of which the soil cores contained sheen and product, respectively. Movement of LNAPL to wells is affected by and related to the characteristics of LNAPL, conductivity of porous media, hydraulic gradient, capillary pressures, and well constructions where LNAPL is located. GW-10 was much deeper and had a longer screen than MW-4. Accumulation of LNAPL in GW-10 was relatively faster than in MW-4 two years ago. Therefore, additional gauging and sampling is needed to delineate LNAPL and evaluate its characteristics including its composition, density, viscosity and mobility in order to identify a potential remedial strategy for LNAPL at the site.

Widespread surface seeps/staining were observed along Sand Creek. Based on the groundwater and Sand Creek elevations surveyed in August 2020, the water level at MW-06, which is the closest well to the creek is approximately 7 to 8 ft higher than the creek elevation. Therefore, the groundwater may flow toward Sand Creek, and discharge as seepage on the streambank. Sand Creek at the site appears to be ephemeral and for much of the year the seeps are dry. It is not likely that the groundwater is a major source feeding to Sand Creek but instead, the creek only flows during and following periods of rainfalls. In addition, the surface water and sediment samples from Sand Creek collected during the RI did not contain concentrations of the COPCs that pose unacceptable risks to human health. No elevated COPCs were found in the closest upgradient well, MW-06 although high metal concentrations were found in the well. Elevated iron content in the groundwater is oxidized, becomes a less dissolved form and precipitates out at the streambank when it is exposed to the air or by microorganisms, leaving staining and iron red gelatinous slime at the creek bank. Slug tests conducted in August 2020 at monitoring wells as part of the data gap investigation evaluated a geometric mean hydraulic conductivity of 0.35 feet per day (ft/day), which is typical for a sandstone aquifer and much lower than the more permeable sand or silt aquifers. Therefore, the groundwater at the site which appears to slowly move through soil perched on bedrock and sandstone was not found to significantly impact Sand Creek.

Benzene, naphthalene, benzo(a)anthracene, 2-methylnphthalene, and dissolved metals (lead, arsenic, iron, cobalt, and manganese) exceeded their Maximum Contaminant Levels (MCLs) or EPA Regional Screening Levels (RSLs) in multiple groundwater wells. BAP however exceeded its MCL of 0.2 microgram per liter (µg/L) only in WPA-GW-02. The benzene plume is located in the north of the Wilcox Process Area and is not delineated to the northwest. Naphthalene and lead concentrations exceeded the respective RSL of 0.12 µg/L and MCL of 15 µg/L in both Lorraine and Wilcox Process Areas. Exceedances of arsenic and manganese are widespread at the site. The COPC groundwater plumes are not fully delineated (Appendix B).

2.7 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

The following sections present the methodology and summary of results for the HHRA.

2.7.1 Introduction

The role of the HHRA is to quantify the risks associated with potential exposure to hazardous substances at a site in the absence of any remedial action or control, including institutional controls (ICs) (e.g. property use restrictions). Therefore, a HHRA was performed to estimate the probability and magnitude of potential adverse human health effects from exposure to contaminants associated with the site assuming no remedial action was taken. The HHRA aids in risk management decisions and provides the basis for taking action. The HHRA identifies the exposure areas, exposure pathways, and contaminants that may be considered for remedial action.

The HHRA followed EPA methodology and included the following information: the methodology for data grouping and identification of COPCs, the exposure assessment, the toxicity assessment, the site-specific risk assessment results, and the uncertainty analysis.

2.7.2 Data Grouping and COPC Identification

Sampling for the RI occurred over multiple field events from August 2016 to December 2018. As part of the RI field investigation, soil, groundwater, sediment, surface water, indoor air, and sub-slab soil gas samples were collected. These samples were evaluated quantitatively in the HHRA. Additionally, waste material samples and passive soil gas samples were also collected to support the RI; however, these samples were not evaluated quantitatively in the HHRA. The HHRA also evaluated soil sample results from residential yards that were collected by EPA in 2015.

The EPA RSLs (EPA 2019) were the primary screening levels used for risk-based screening purposes in the HHRA. COPCs were identified by comparing the maximum detected concentration to the appropriate EPA RSL. COPCs are chemicals that are carried through the quantitative exposure and risk estimate portions of the HHRA.

Based upon the process areas and site use, the site was divided into five major former operational areas: the Wilcox and Lorraine Process Areas, the East and North Tank Farms, and the Loading Dock Area. The HHRA determined COPCs and evaluated potential risk concerns based upon these five operational areas. As stated in the previous section, Section 2.6, the site COPCs include PAHs SVOCs, VOCs, and metals for soil, sediment, and groundwater; and PAHs and metals for surface water.

2.7.3 Exposure Assessment

In the exposure assessment, the receptors of concern and potential exposure pathways were identified. The COPCs in site environmental media are converted into systemic doses, taking into account contaminant concentrations, rates of contact (e.g., ingestion rates), and absorption rates of different COPCs. The magnitude, frequency, and duration of these exposures are then integrated to obtain estimates of daily doses over a specified period of time (e.g., lifetime, activity-specific duration). Figure 2-7 presents the HHRA CSM. The CSM presents the exposure pathways that were qualitatively evaluated in the HHRA.

Within the exposure assessment, exposure point concentrations (EPCs) were derived to quantify concentrations of COPCs. For the HHRA, the EPCs represent the concentration of COPCs in media of concern that a potential receptor is expected to contact over a designated exposure period. The EPCs were represented by the 95 upper confidence limit of the mean (95UCLM) in each medium of concern. For the assessment of lead in soil, the average concentration was used. It is noted that the soil exposure areas evaluated in the HHRA are significantly larger than a "typical" residential yard.

2.7.4 Toxicity Assessment

The toxicity assessment considers the types of potential adverse health effects associated with exposures to COPCs, the relationship between the magnitude of exposure and potential adverse effects, and related uncertainties, such as the weight of evidence of a particular COPC carcinogenicity in humans. Toxicity values were selected in keeping with appropriate exposure durations and EPA guidance (EPA 2003). The following tiers were followed in the selection of toxicity values for the HHRA:

- Tier 1 – Integrated Risk Information System (EPA 2019)

- Tier 2 – EPA's Provisional Peer Reviewed Toxicity Values, which are developed by the Office of Research and Development, the National Center for Environmental Assessment, and the Superfund Health Risk Technical Support Center

- Tier 3 – Other toxicity values were taken from additional EPA and non-EPA sources and were chosen based on the most current and best peer-reviewed source available. The California Environmental Protection Agency (CalEPA) (2019), Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database, CalEPA (2009) Cancer Potency Values, and the Agency for Toxic Substances and Disease Registry (ATSDR) (2019) Minimal Risk Levels were the Tier 3 sources utilized for this HHRA.

2.7.5 Risk Characterization

The final step in the HHRA is the characterization of the potential risks associated with exposure to chemicals detected at a site. The HHRA evaluated each of the five process areas for potential cancer risks and noncancer hazards from soil, sediment, surface water, groundwater, and ambient air. Potential exposures to surface water and sediment at the site were within the EPA acceptable cancer risk range, and noncarcinogenic hazards were below the level of concern. Therefore, these media are not expected to pose human health concerns. Carcinogenic risks for all receptors' exposure to soil were also within the EPA acceptable risk range. Potential health concerns were identified for exposure to soil (noncarcinogenic hazards and lead) and groundwater.

The following table presents a summary of the HHRA results.

Receptor	Media	HHRA Results Carcinogenic Risks[1]	 Noncarcinogenic Hazards[1]	COPC Contributing Significantly to Results[2]
North Tank Farm: *Surface Soil*				
Child Resident[3]	Surface soil[4]	5×10^{-5}	2	NA[5]
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	$\mathbf{5 \times 10^{-5}}$	**3**	
Adult Resident[3]	Surface soil[4]	5×10^{-5}	0.8	NA
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	$\mathbf{5 \times 10^{-5}}$	**0.8**	
Construction Worker	Surface soil	1×10^{-7}	0.2	NA
	Total	$\mathbf{1 \times 10^{-7}}$	**0.2**	
Commercial Worker	Surface soil	8×10^{-7}	0.05	NA
	Total	$\mathbf{8 \times 10^{-7}}$	**0.05**	
Adolescent Trespasser	Surface soil	2×10^{-7}	0.02	NA
	Surface water	2×10^{-6}	0.1	NA
	Sediment	1×10^{-6}	0.04	NA
	Total	$\mathbf{4 \times 10^{-6}}$	**0.2**	
North Tank Farm: *Subsurface Soil*				
Child Resident[3]	Subsurface Soil	5×10^{-6}	1	NA
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	$\mathbf{1 \times 10^{-5}}$	**1**	
Adult Resident[3]	Subsurface soil	5×10^{-6}	0.1	NA
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	$\mathbf{1 \times 10^{-5}}$	**0.1**	
Construction Worker	Subsurface soil	1×10^{-7}	0.3	NA
	Total	$\mathbf{1 \times 10^{-7}}$	**0.3**	
Lorraine Process Area: *Surface Soil*				
Child Resident[3]	Surface soil[4]	3×10^{-5}	3	NA[5]
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	$\mathbf{4 \times 10^{-5}}$	**3**	
Adult Resident[3]	Surface soil[4]	3×10^{-5}	1	NA
	Surface water	5×10^{-6}	0.03	NA

Receptor	HHRA Results: Media	HHRA Results: Carcinogenic Risks[1]	HHRA Results: Noncarcinogenic Hazards[1]	COPC Contributing Significantly to Results[2]
	Sediment	4×10^{-6}	0.006	NA
	Total	**4×10^{-5}**	**1**	
Construction Worker	Surface soil	2×10^{-7}	0.1	NA
	Total	**2×10^{-7}**	**0.1**	
Commercial Worker	Surface soil	1×10^{-6}	0.04	NA
	Total	**1×10^{-6}**	**0.04**	
Adolescent Trespasser	Surface soil	3×10^{-7}	0.01	NA
	Surface water	2×10^{-6}	0.1	NA
	Sediment	1×10^{-6}	0.04	NA
	Total	**4×10^{-6}**	**0.2**	
Lorraine Process Area:*Subsurface Soil*				
Child Resident[3]	Subsurface soil	5×10^{-6}	0.6	NA
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	**1×10^{-5}**	**1**	
Adult Resident[3]	Subsurface soil	5×10^{-6}	0.06	NA
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	**1×10^{-5}**	**0.1**	
Construction Worker	Subsurface soil	1×10^{-7}	0.2	NA
	Total	**1×10^{-7}**	**0.2**	
Loading Dock Area: *Surface Soil*				
Child Resident[3]	Surface soil[4]	7×10^{-5}	5	Cancer Risks: NA Non-Cancer Hazards: Cobalt
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	**8×10^{-5}**	**6**	
Adult Resident[3]	Surface soil[4]	7×10^{-5}	2	NA[5]
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	**8×10^{-5}**	**2**	
Construction Worker	Surface soil	2×10^{-7}	0.3	NA
	Total	**2×10^{-7}**	**0.3**	
Commercial Worker	Surface soil	1×10^{-6}	0.09	NA
	Total	**1×10^{-6}**	**0.09**	
Adolescent Trespasser	Surface soil	3×10^{-7}	0.03	NA
	Surface water	2×10^{-6}	0.1	NA
	Sediment	1×10^{-6}	0.04	NA
	Total	**4×10^{-6}**	**0.2**	
Loading Dock Area: *Subsurface Soil*				
Child Resident[3]	Subsurface Soil	5×10^{-6}	2	NA[5]
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	**1×10^{-5}**	**2**	
Adult Resident[3]	Subsurface soil	5×10^{-6}	0.2	NA
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	**1×10^{-5}**	**0.2**	

Receptor	Media	HHRA Results: Carcinogenic Risks[1]	HHRA Results: Noncarcinogenic Hazards[1]	COPC Contributing Significantly to Results[2]
Construction Worker	Subsurface soil	2×10^{-7}	0.4	NA
	Total	**2×10^{-7}**	**0.4**	
Wilcox Process Area: *Surface Soil*				
Child Resident[3]	Surface soil[4]	4×10^{-5}	10	**Cancer Risks:** NA **Non-Cancer Hazards:** Cobalt, copper, iron, benzo(a)pyrene
	Groundwater	7×10^{-3}	50	**Cancer Risks**: Arsenic, benzene, ethylbenzene **Non-Cancer Hazards**: Arsenic, cyanide, iron, benzene
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	**7×10^{-3}**	**60**	
Adult Resident[3]	Surface soil[4]	4×10^{-5}	3	NA[5]
	Groundwater	7×10^{-3}	93	**Cancer Risks:** Arsenic, naphthalene, benzene, ethylbenzene **Non-Cancer Hazards**: Arsenic, cyanide, naphthalene, benzene, m,p-xylene, o-xylene
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	**7×10^{-3}**	**96**	
Construction Worker	Surface soil	4×10^{-7}	0.3	NA
	Groundwater	9×10^{-5}	33	**Cancer Risks**: NA **Non-Cancer Hazards**: Naphthalene, benzene, m,p-xylene
	Total	**9×10^{-5}**	**33**	
Commercial Worker	Surface soil	2×10^{-6}	0.06	NA
	Groundwater	8×10^{-4}	12	**Cancer Risks**: Arsenic, benzene **Non-Cancer Hazards**: Benzene
	Total	**8×10^{-4}**	**12**	
Adolescent Trespasser	Surface soil	1×10^{-6}	0.03	NA
	Surface water	2×10^{-6}	0.1	NA
	Sediment	1×10^{-6}	0.04	NA
	Total	**5×10^{-6}**	**0.2**	

Receptor	Media	HHRA Results: Carcinogenic Risks[1]	HHRA Results: Noncarcinogenic Hazards[1]	COPC Contributing Significantly to Results[2]
Wilcox Process Area: *Subsurface Soil*				
Child Resident[3]	Subsurface Soil	3×10^{-5}	1	NA
	Groundwater	7×10^{-3}	50	**Cancer Risks**: Arsenic, benzene, ethylbenzene **Non-Cancer Hazards**: Benzene, arsenic, cyanide

Receptor	HHRA Results: Media	Carcinogenic Risks[1]	Noncarcinogenic Hazards[1]	COPC Contributing Significantly to Results[2]
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	**7×10^{-3}**	**52**	
Adult Resident[3]	Subsurface soil	3×10^{-5}	0.1	NA
	Groundwater	7×10^{-3}	93	**Cancer Risks**: Arsenic, naphthalene, benzene, ethylbenzene **Non-Cancer Hazards**: Arsenic, cyanide, naphthalene, benzene, m,p-xylene, o-xylene
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	**7×10^{-3}**	**93**	
Construction Worker	Subsurface soil	4×10^{-7}	0.3	NA
	Groundwater	9×10^{-5}	33	**Cancer Risks**: NA **Non-Cancer Hazards**: Naphthalene, benzene, m,p-xylene
	Total	**9×10^{-5}**	**34**	
East Tank Farm: ***Surface Soil***				
Child Resident[3]	Surface soil[4]	5×10^{-5}	3	NA[5]
	Surface water	5×10^{-6}	0.3	NA
	Sediment	4×10^{-6}	0.1	NA
	Total	**6×10^{-5}**	**3**	
Adult Resident[3]	Surface soil[4]	5×10^{-5}	1	NA
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	**6×10^{-5}**	**1**	
Construction Worker	Surface soil	2×10^{-7}	0.2	NA
	Total	**2×10^{-7}**	**0.2**	
Commercial Worker	Surface soil	1×10^{-6}	0.05	NA
	Total	**1×10^{-6}**	**0.05**	
Adolescent Trespasser	Surface soil	4×10^{-7}	0.02	NA
	Surface water	2×10^{-6}	0.1	NA
	Sediment	1×10^{-6}	0.04	NA
	Total	**4×10^{-6}**	**0.2**	

Receptor	HHRA Results: Media	Carcinogenic Risks[1]	Noncarcinogenic Hazards[1]	COPC Contributing Significantly to Results[2]
East Tank Farm: ***Subsurface Soil***				
Child Resident[3]	Subsurface Soil	8×10^{-6}	1	NA
	Surface water	5×10^{-6}	0.3	NA

Receptor	HHRA Results Media	Carcinogenic Risks[1]	Noncarcinogenic Hazards[1]	COPC Contributing Significantly to Results[2]
	Sediment	4×10^{-6}	0.1	NA
	Total	**2×10^{-5}**	**1**	
Adult Resident[3]	Subsurface soil	8×10^{-6}	0.1	NA
	Surface water	5×10^{-6}	0.03	NA
	Sediment	4×10^{-6}	0.006	NA
	Total	**2×10^{-5}**	**0.1**	
Construction Worker	Subsurface soil	2×10^{-7}	0.2	NA
	Total	**2×10^{-7}**	**0.2**	

Notes:
1. Total Risks and hazards presented for each Area do not equal the sum of individual environmental media due to rounding.
2. A significant contributor is defined as a COPC that contributes greater than 10^{-5} carcinogenic risk or non-carcinogenic hazard greater than 1.
3. Carcinogenic risks for the resident adult and child are combined and presented as a total lifetime cumulative carcinogenic risk.
4. Surface soil risks include ingestion of homegrown produce and beef.
5. A breakdown by target organ did not reveal any non-carcinogenic hazards greater than 1.

NA = Not Applicable.

Lead was identified as a COC in surface and subsurface soil within the Lorraine Process Area and the Wilcox Process Area, and surface soil within the East Tank Farm. Therefore, soil within these areas is to be addressed by the FS.

The HHRA evaluated potential human health concerns based on the entire exposure area. However, these areas are larger than areas that are typically evaluated for residential yards. To further evaluate the surface soil medium of concern and evaluate potential concerns for smaller exposure areas (i.e., potential residential yards), sample results were reviewed to determine if areas of high concentration are present within the five soil exposure areas. Areas of high concentration were determined as concentrations that exceed the residential soil RSL by two orders of magnitude (i.e., 100 times). The only chemical that exceeded this criterion was BaP within the Wilcox Process Area and Lorraine Process Area. Therefore, the HHRA noted potential isolated areas of BaP that may be potential human health concerns for residential receptors. Section 2.7.6 of this FS Report presents additional analysis of BaP that was performed after the Final HHRA.

Groundwater potential risks were assessed based upon monitoring well results within the perched aquifer. Potential risk concerns for exposure to groundwater within the perched aquifer were determined for all receptors' exposure to groundwater. Primary contributors to risk concerns were multiple metals (arsenic, cyanide, and iron) and VOCs (benzene, naphthalene, ethylbenzene, and m- and p-xylenes). The maximum detected concentration of VOCs was found in monitoring well MW-04, located in the Wilcox Process Area. Due to the low frequency of detection, the EPC for VOCs in monitoring wells is the maximum detected concentration. The maximum detected concentration for VOCs within MW-04 is approximately three orders of magnitude higher than detections in other wells. It is also noted that these VOCs were not detected in the residential groundwater wells. This well is located in the northeast area of the Wilcox Process Area. Therefore, groundwater risk concerns based upon monitoring well results are centralized within the Wilcox Process Area. Groundwater was also identified as a media of concern in the HHRA.

2.7.6 Additional Evaluation of Potential Risk Concerns

The high detections of BaP were reviewed to determine if risk concerns associated with individual parcels exist. For the Lorraine Process Area, sample location LOR-TP-09 is located within the northwest end of the area, along E0810 Road, and just north of the church's parking lot. This grassy area is approximately 1 acre in area, which is equivalent to a residential yard for the area. The high concentrations were detected in the samples from 0 to 0.5 ft bgs. All samples collected within this area were combined to determine an EPC for this exposure area. Samples collected within this area include: SB-01, SB-02, SB-07, SB-08, SB-09, and TP-09. ProUCL was used to determine the 95UCLM for this area. The resulting BaP EPC was 24.1 mg/kg. The EPA RSL calculator was used to determine potential risk concerns for a resident (adult and child) within this area. The RSL calculator outputs are provided in Appendix C. The resulting cumulative, lifetime excess carcinogenic risk was 2×10^{-4}. Noncarcinogenic hazards were 1 and 0.2 for the resident child and resident adult, respectively. As a result, BaP is also identified as a COC to be addressed in the FS.

2.8 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

EA conducted a SLERA in January 2020 following Steps 1, 2 and 3 of EPA's Ecological Risk Assessment Guidance (EPA 1997, 1998). This section provides an overall summary of the ecological risk assessment.

2.8.1 Introduction

The purpose of the SLERA was to characterize and quantify potential environmental impacts from residual chemicals in soil, sediment, and surface water from site activities. The assessment was conducted in accordance with the process outlined in the document, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997) and other relevant EPA guidance.

The process for ERA outlined in EPA guidance includes eight steps (EPA 1997, 1998). Steps 1 and 2 represent the SLERA. The SLERA uses precautionary assumptions regarding exposure and toxicity to develop a CSM and identify constituents of potential ecological concern (COPECs). The CSM defines complete and significant exposure pathways and identifies assessment and measurement endpoints. The screening level evaluation relies on chemical analytical data.

Step 3 of the SLERA process is the Baseline Risk Assessment Problem Formulation (BRAPF). The BRAPF draws from the risk evaluation performed in the SLERA to identify COPECs, exposure pathways, assessment endpoints, and risk questions requiring further consideration.

The BRAPF often includes a refinement of the screening level risk calculations through more realistic or more relevant exposure and toxicity data. The goal of the BRAPF is to provide a clear definition of the potential ecological risks for the site. This problem formulation forms the basis for either further assessment or, in cases where sufficient data are available, risk management if necessary. In the case of this site, SLERA and BRAPF refinement of risk calculations were performed.

2.8.2 Ecological Conceptual Site Model

Figure 2-8 presents the ecological CSM which illustrates potential sources of chemicals and exposure pathways (EA 2020c).

Potential source areas include the skimming and cracking plant, re-distillation battery, stills, cooling ponds, a lead additive area, approximately 10 buildings that housed refinery operations, storage tanks, and other related refinery structures historically located on the Lorraine and Wilcox Process Areas. Other potential source areas include former locations of approximately 80 bulk storage tanks of various sizes located at the Lorraine and Wilcox Process Areas, as well as the East and North Tank Farms. Surficial waste material was also identified and sampled at the Loading Dock Area.

Crude oil, fuel oil, gas oil, distillate, kerosene, naphtha, and benzene (petroleum ether), acids, and other refined products were reportedly stored on the property (EA 2016a). Periodic releases of crude oil, sludge, and refined product occurred in these areas during operations. These releases may have been discharged to surface and subsurface soil, and subsequently migrated to groundwater, surface water, and sediment. VOCs may have also migrated into the vadose zone as soil gas.

Potential receptors evaluated in the SLERA for the site include plants, soil invertebrates, amphibians and reptiles, birds, mammals, benthic invertebrates, and aquatic organisms. Potential ecological receptors and scenarios are shown in the CSM (Figure 2-8).

2.8.3 SLERA Results

The SLERA used conservative assumptions, including conservative toxicity reference values (TRVs) and input parameters for food web models (e.g., 100% site use, 100% earthworm ingestion, etc.). The evaluation also assumed maximum exposure scenarios (e.g., maximum ingestion rates and EPCs). Modifications were conducted as part of Step 3 of the ERA process that used more realistic EPCs (i.e., 95UCLM of the data) and incorporated lowest effect level TRVs. Despite the modifications, the SLERA identified potential risks (based on hazard quotients [HQs] greater than 1) for the following receptors and COPECs as showed in the following table (EA 2020c).

Area	Receptor	COPEC (HQ_{95UCLM})
Wilcox and Lorraine Process Area	Plants	Chromium (9) Copper (3) Lead (3) Vanadium (7) Zinc (3)
	Soil Invertebrates	Chromium (22) Hexavalent chromium (3) Copper (3) Mercury (2) Zinc (4) Isopropylbenzene (4) Xylene (3)
	Insectivorous Mammals	Lead (2)
	Insectivorous Birds	Lead (9) Vanadium (5)
	Herbivorous Birds	Lead (3)
Tank Farm and Loading Dock Area	Plants	Chromium (8) Manganese (2) Vanadium (6)
	Soil Invertebrates	Chromium (20) Isopropylbenzene (80)
	Insectivorous Birds	Lead (2) Vanadium (4)
Ponds	Aquatic Organisms	Cadmium (27) Lead (10) Benzo(a)pyrene (4)
Streams	Benthic Invertebrates	Total PAHs (4)
	Aquatic Organisms	Manganese (4)
Note: HQs in parentheses are based on 95UCLMs, not maximum concentrations.		

2.8.4 SLERA Refinement

SLERA refinement was conducted to evaluate COPECs for lower trophic level receptors (e.g., benthic invertebrates, plants, and soil invertebrates) that had SLERA HQs greater than 1 based on 95UCLMs. Detailed discussion is included in Appendix C of this report. The findings of the risk assessment are as following:

- The risk assessment determined that potential risks associated with exposures to lead in site soil (all 5 areas) are present for plants, insectivorous mammals, insectivorous birds, and herbivorous birds. Areas of concern are collocated with human health remediation areas; therefore, remediation based on an ecological lead exposure PRG is not proposed for soil.

- The risk assessment determined that potential risks associated with exposures to vanadium in the site soil (all 5 areas) are present for plants and insectivorous birds. Areas of concern are collocated with human health remediation areas; therefore, remediation based on an ecological vanadium exposure PRG is not proposed for soil.

- Potential risks to aquatic organisms in the ponds (cadmium, lead, BaP) and streams (manganese) from elevated concentrations of contaminants in the water column are likely to be reduced following removal of contaminated soil in the uplands. No remediation based on potential risks associated with surface water is proposed.

- Concentrations of total PAHs in stream sediment, when compared to the probable effects level (PEL) of 16.8 mg/kg (MacDonald et al 1996) indicates no potential risk to benthic organisms from total PAHs in stream sediments; therefore, no remediation based on potential risks to benthic invertebrates from PAHs is proposed.

- Because of infrequent detections of volatile organic compounds, the volatile nature of the chemicals, the absence of direct toxicological studies, and the unsubstantiated theoretical nature of the soil screening values, it is not expected that these VOCs would result in unacceptable risk to populations of soil invertebrates; therefore, no remediation based on potential risks to soil invertebrates from VOCs is proposed.

- It is unlikely that there would be adverse impacts to the plant or soil invertebrate communities at the site from sporadic elevated concentrations of metals (zinc, manganese, copper, and chromium) based on the following, and as a result, no remediation based on potential risks to plants or soil invertebrates is proposed.

  - Low HQs identified in the SLERA, based solely on a screen against Ecological Soil Screening Levels or screening benchmarks from Efroymson et al. (Efroymson et al 1997a,b).
  - Low potential for uptake and toxicity from naturally occurring metals, many of which are essential nutrients.
  - Sporadic elevated concentrations not linked to facility activities.
  - Lack of sufficient ecological habitat from long-term and/or continued future industrial, residential, and agricultural usage of many portions of the site.
  - Removal of select concentrations of metals during excavations for lead and/or BaP, thus reducing the overall HQs.

3. GROUNDWATER DATA GAP AND POTENTIAL TECHNOLOGIES

Groundwater was investigated and identified to pose unacceptable risk to human health as indicated in the previous section of this FS Report. A data gap investigation was conducted following the RI in August 2020. The following subsection summarizes the data gap investigation results, and detailed results are provided in Appendix B. Although this FS only addresses the soil contamination, per the request from EPA, this section also presents potential technologies that may be considered for the future groundwater remediation. In addition, in support of future groundwater FS and remediation, calculation of groundwater PRGs was conducted and discussed in this section as well. The PRGs for groundwater are included in Appendix C.

3.1 GROUNDWATER DATA GAP

The HHRA identified potential risks exist for exposure to the groundwater associated with the perched shallow groundwater unit, which could be utilized for domestic use, in the Wilcox Process Area and Lorraine Process Area.

Due to the limited groundwater data available, it was determined that a data gap investigation would be required to evaluate the site groundwater conditions. Therefore, additional groundwater investigation was conducted in August 2020. Temporary wells were installed, and groundwater samples were collected at old and new monitoring wells, temporary wells, and water wells. Aquifer tests were performed at existing monitoring wells to evaluate site-specific hydraulic parameters. Groundwater levels were gauged, and a survey of Sand Creek was conducted to evaluate potential communication between groundwater and the creek. The data gap investigation results are summarized in the Technical Memorandum on Data Gap Investigation (Appendix B).

3.2 POTENTIAL GROUNDWATER REMEDIAL TECHNOLOGIES

A few potential technologies for the site groundwater can be explored based on the current understanding of the site, i.e., pump-and-treat, *in situ* enhanced bioremediation (ISB); *in situ* chemical oxidation (ISCO), and *in situ* stabilization and solidification (ISS). A full evaluation of alternatives should be conducted once more data are collected.

The LNAPL's quantity, mobility and recoverability are currently not known, but if the LNAPL is found mobile and highly recoverable, potentially pump-and-treat or skimming technology can be used to recover the LNAPL for offsite disposal. Based on the LNAPL observation at MW-04, however, its recovery rate is likely low and pumping may not be effective. Depending on remedial objectives, for mass control and reduction of mobility, ISS may be used to physically/ chemically bind LNAPL with stabilizing reagents. However, ICs should be put in place to protect the stabilized area, and long term monitoring may also be necessary to monitor potential leaching of stabilized contaminants into the dissolved phase.

Similar to LNAPL, if the dissolved phase plume is massive and unstable, pump-and-treat can be used to hydraulically control the plume and treat the contaminants. However, the pump-and-treat system will need components that treat both metals and organic contaminants from the commingled plumes. Granular activated carbon or other absorbing materials can be used to treat the recovered petroleum hydrocarbons in the system, but are not effective for metals. Therefore, another treatment train shall be needed, which may include an ion exchange system or a pH adjuster to precipitate metals. The system can become complex, and costs can be high for operation and maintenance. In addition, low recovery rates of the temporary wells and low hydraulic conductivity observed at the site may limit the cost-effectiveness of a pump-and-treat system.

ISB is an *in situ* technology to consider, and it involves injection of amendments into groundwater to stimulate aerobic biodegradation of benzene, naphthalene, and other petroleum hydrocarbons. Commercially available products of ISB amendments include the oxygen-releasing compounds by Regenesis and PermeOx by PeroxyChem. Although ISB will probably not directly address the lead, arsenic, and other dissolved metals in the groundwater, added oxygen-containing compounds can also react with dissolved metals, specifically dissolved iron and manganese, to generate iron and manganese oxides, which can bind and precipitate lead and arsenic in the groundwater.

ISCO as another *in situ* technology involves injection of chemical oxidant amendments into the subsurface to transform contaminants in groundwater into innocuous byproducts. Common ISCO reagents include hydrogen peroxide, sodium persulfate, potassium permanganate, sodium percarbonate, and ozone. These reagents can efficiently oxidize a wide range of compounds including benzene, naphthalene, and other organic compounds. However, ISCO may mobilize metals, especially for redox sensitive metals (i.e., chromium, arsenic, and lead). Therefore, it is not applicable for the areas with metal exceedances to make metal plumes worse. In addition, LNAPL presence at the site may lower the effectiveness of ISCO by coating the reagent particles and reducing reaction potential with the contaminants.

Provect-OX®, a commercial product made by Provectus Environmental Products, Inc., was found to be able to oxidize naphthalene and pentachlorophenol in the groundwater in another EPA Superfund site without increasing in metal concentrations. Provect-OX® contains persulfate (as an oxidant) and ferric iron (as an activation agent) in a single premixed package. It has been found that residual iron and sulfate generated from persulfate decomposition can be used as electron acceptors for facultative reductive processes. Therefore, Provect-OX® may promote secondary enhanced bioremediation to manage residuals in the groundwater, which may be applicable to the site groundwater. A bench scale treatability study for ISCO must be conducted to determine a sufficient dosing of the oxidant to account for natural oxidant demand in the subsurface and also evaluate potential metal mobility caused by the oxidant.

Technologies that require injection target treated areas directly, so enhanced distribution of reagents is very important for improving treatment efficiency. The site's high heterogeneity may be a concern for injected reagents to be evenly distributed to the contaminated subsurface. Therefore, ISS can be an option to overcome the shortcomings at the site. During ISS, a large diameter rig is used to mix and homogenize amendments with soil/groundwater. The mixed materials are then used to form monoliths with certain strength and structural integrity to hold the contaminants in place. The use of monolith structures aide in minimizing leaching to the groundwater. Typical ISS reagents include Portland cement, slag, fly ash, bentonite, organoclay, and powdered activated carbon. ISS can effectively stabilize metals and petroleum hydrocarbons in the groundwater but has been found to not be able to reduce naphthalene leaching potential in some projects. Therefore, it may be used in the source areas to significantly reduce the source contributions to the dissolved plumes. This option can address both soil and groundwater contaminated with LNAPL, metals, and organic compounds at the same time because the rig can mix reagents from unsaturated to saturated zones in one operation. A bench scale treatability study is required to develop an optimal reagent mixture prior to a full scale ISS implementation. In addition, as stated previously, ICs are required to prevent any earth moving activities in the ISS treated area.

Based on data gaps, the groundwater evaluation is taken no further, and the remainder of this FS will focus on soil.

3.3 GROUNDWATER PRG CALCULATION

The HHRA determined that site groundwater COCs are VOCs, including naphthalene. Due to the low frequency of detection, the EPC for VOCs evaluated in the HHRA is the maximum detected concentration. The maximum detected concentration for VOCs were detected within MW-04, within the Wilcox Process Area, and are approximately three orders of magnitude higher than detections in other wells. It is also noted that these VOCs were not detected in the residential groundwater wells. Because no target organs exceeded a noncancer hazard of 1, only chemicals with noncancer hazards greater than 1 are considered COCs.

Groundwater in this area of the site is not currently used as a tap water source and is also a location of significant soil contamination. It is noted that the State of Oklahoma does consider the shallow, perched groundwater at MW-04 as a “General Use Groundwater (Class II),” which can be used for beneficial use (ODEQ 2020). As a result, the restoration of groundwater to potential beneficial use is considered the primary objective for the selection of groundwater PRGs. The PRGs for groundwater are provided in Appendix C.

4. REMEDIAL ACTION OBJECTIVES

This section proposes RAOs and PRGs for the contaminated soils at the site. The section also discusses the ARARs and identifies areas and volumes of contaminated soils exceeding the PRGs and therefore need to be addressed in the FS.

4.1 REMEDIAL ACTION OBJECTIVES

The RAOs were developed for contaminated soils to addressed unacceptable human health risks identified through the risk assessment process. The future land use and contaminant exposure pathways were included in the RAO development. The soil RAOs are to:

- Prevent human exposure to the soils with concentrations of COCs exceeding the PRGs.

- Minimize and prevent migration of soil contaminants into the groundwater, surface water, and other site soils.

4.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Remedial actions must protect public health and the environment. Section 121(d) of CERCLA requires that federal and state ARARs be identified and that response actions achieve compliance with the identified ARARs. This requirement makes CERCLA response actions consistent with pertinent federal and state environmental requirements as well as adequately protecting public health and the environment. Therefore, compliance with the ARARs is included in the development and evaluation of the remedial alternatives.

4.2.1 Definition of Applicable or Relevant and Appropriate Requirements

As defined in the NCP, "applicable requirements" are cleanup standards, standards of control, criteria, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only the state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable (40 CFR 300.5).

Relevant and appropriate requirements may not specifically apply but may address similar issues or situations that might be encountered at the site. A requirement must be either applicable or both relevant and appropriate to be selected as an ARAR.

4.2.2 Classifications of Applicable or Relevant and Appropriate Requirements

ARARs for remedial alternatives can be generally classified into the following three categories:

- ***Chemical-Specific*** are usually based on health- or risk-based numerical values or methodologies used to determine acceptable amounts or concentrations of chemicals that may be found in, or discharged to the environment, i.e., MCLs or State Water Quality Standards.

- ***Location-Specific*** are restrictions placed on the concentrations of hazardous substances or activities solely because they are in certain environmentally sensitive areas. Some examples of special locations regulated under various federal laws include floodplains, wetlands, historically significant cultural resources, and sensitive ecosystems or habitats.

- ***Action-Specific*** are usually technology- or activity-based requirements or limitations on actions or conditions involving specific substances.

In addition to these three categories, some EPA and State guidelines also need “to be considered” (TBC). The TBC are non-promulgated advisories, non-enforceable guidelines or criteria and standards useful for developing a remedial action criterion or evaluating protection of human health and / or environment. Examples include EPA reference doses and risk specific doses that may be used for determining the level of cleanup.

Table 4-1 presents the ARARs for the site. These ARARs are identified based on the site conditions and in consideration of potential remedial alternatives developed in the FS.

4.3 PRELIMINARY REMEDIATION GOALS

PRGs were determined for each of the chemicals identified as COCs. PRGs were developed for chemicals with cancer risks greater than 10^{-6} and target organ specific Hazard Index (HI) greater than 1. Detailed information on PRG calculations is included in Appendix C. The site-specific PRGs are chemical limits calculated upon toxicity values and site-specific exposure conditions evaluated in the HHRA (EA 2020). The HHRA determined potential health concerns for selected receptors exposures to lead in soil (Lorraine Process Area, Wilcox Process Area, and East Tank Farm). Additionally, soil sample results were reviewed to determine if areas of high concentration are present within individual parcels. Based upon this evaluation, BaP was also identified as a COC.

The following equations were used to calculate site-specific PRGs:

<u>For carcinogens:</u>

$$Site - Specific\ PRG = \frac{EPC}{Risk} \times TR$$

Where,
TR = target carcinogenic risk level (i.e., 10^{-6}, 10^{-5}, 10^{-4})
Risk = chemical-specific cumulative carcinogenic risk shown in HHRA
EPC = chemical-specific exposure point concentration presented in HHRA.

For non-carcinogens:

$$Site - Specific\ PRG = \frac{EPC}{HQ} \times THQ$$

Where,
THQ = target hazard quotient (i.e., 1)
HQ = target organ specific and chemical-specific total hazard quotient shown in HHRA
EPC = chemical-specific exposure point concentration presented in HHRA.

The proposed PRGs for site soil COCs are listed below:

- Lead - 200 mg/kg (for residential use); and 400 mg/kg (for industrial use)
- BaP – 1.2 mg/kg (residential and industrial use)

It is assumed that addressing the risks to human health would resolve the ecological risks based on the future land use, which is assumed to be limited to residential use at the site, with the exception of the Wilcox Process Area where there is only one area in the north that is considered as residential and the rest of the process area is assumed as industrial and commercial use.

Note that lead is classified as a probable human carcinogen. However, EPA has not published a slope factor or inhalation unit risk for quantifying carcinogenic risks. Blood lead levels are the indicators of excess lead exposure in humans. To ensure the appropriateness of PRG selection, lead PRGs were determined based upon the blood-lead levels of 5, 8, and 10 micrograms per deciliter of lead in blood. The Integrated Exposure Uptake Biokinetic (IEUBK) model was used to determine the appropriate PRGs for the various blood-lead levels. It is noted that the IEUBK model does not provide a printout of the PRG determination. For the worker, the EPA Adult Lead Model was used to determine the appropriate PRGs for the various blood-lead levels. The final selection of the appropriate PRG depends upon identified land use and remedial feasibility.

4.4 OCCURRENCE AND VOLUME OF SOILS ABOVE PRGS

The soils exceeding the lead PRGs are identified across the Wilcox and Lorraine Process Areas and the west of East Tank Farm. Figures 2-5 and 2-6 show the exceedances. Most of the exceedances are in the surface soil, 0 to 2 ft bgs. There are two locations, one in the Lorraine Process Area and the other in the Wilcox Process Area where the lead exceedances are deeper, from 2 to 6 ft bgs.

The soils exceeding the BaP PRG are also located in the Lorraine and Wilcox Process Areas. One exceedance is co-located with lead exceedance at the northeast of the Wilcox Process Area (Figure 2-6). The depth of BaP contamination is to 6 ft bgs at three locations, from 2 to 8 ft bgs at one location, from 2 to 13 ft bgs at one location, and from 0 to 2 ft bgs at the remaining locations.

Additional sampling is needed to refine the extent of the contaminated soils, and delineation sampling will need to be conducted during the remedial design. For the purpose of this FS, the exceedance boundaries are estimated based on the assumption that a boundary line is in the midpoint between the sampling point with exceedance and the nearby sampling point of non-exceedance. The estimated volume of impacted soils including sediment are as follows:

- Lorraine Process Area – 4,280 cubic yards (cys) for lead and 710 cys for BaP
- Wilcox Process Area – 15,390 cys for lead, 7,180 cys for BaP, and 3,260 cys for both lead and BaP. In addition, 1,000 cy of sediment for lead
- East Tank Farm – 8,450 cys for lead.

In summary, a total of 40,270 cys of contaminated soil and sediment with concentrations above the PRGs are to be addressed by this FS (Figures 2-5 and 2-6).

5. DEVELOPMENT AND SCREENING OF TECHNOLOGIES

This section describes the process of development and screening of technologies. The development process starts by identifying general response actions (GRAs) and associated technologies for soils. The remedial technologies are then screened under the three criteria: effectiveness, implementability, and cost.

5.1 GENERAL RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

GRAs may include institutional actions, containment, treatment, removal, disposal, or a combination of these as described in the EPA 1988 guidance (EPA 1988). As required by the NCP (40 CFR §300.430.e.6), selected remedial alternatives must include no further action (NFA) to be used as the baseline against which the effectiveness of all other alternatives are evaluated. Thus, NFA is included in the alternative evaluation for the site soil.

NFA means nothing is done to the site. NFA does not control, contain, or remediate contaminant sources, and it does not reduce the mobility, volume, or toxicity of the contamination at the site.

In addition, ICs are also included in evaluation of alternatives. ICs may include restrictions on land use, access restrictions, environmental monitoring, security measures, notification, and education advisories to inform the public and adjacent landowners about the site. Common ICs include zoning, enforceable land use restrictions (i.e., deed notice and covenant restriction), and long-term environmental monitoring.

The GRAs suitable for the site soils include following:

- NFA
- ICs
- Containment
- Removal / disposal
- Treatment.

Table 5-1 presents the GRAs and their individual technologies considered in this section.

5.2 REMEDIAL TECHNOLOGY SCREENING

This section presents and screens the remedial technologies presented in Table 5-1.

5.2.1 Preliminary Screening Criteria

Three preliminary screening criteria (i.e., effectiveness, implementability, and cost) were used to screen the remedial technologies. Definitions for these criteria are presented below.

Effectiveness is a measure of a technology's ability to: (1) reduce toxicity, mobility, or volume; (2) minimize residual risks; (3) afford long-term protection; (4) comply with ARARs;

(5) minimize short-term impacts; and (6) achieve protectiveness in a limited duration. Technologies that are significantly less effective than other technologies may be eliminated from the alternative development process. Technologies that do not provide adequate protection of human health and the environment are also eliminated from further consideration.

The effectiveness evaluation is focused on the following elements:

- Potential effectiveness of technologies in handling the areas or volumes of the soil to meet the RAOs.

- Potential impacts to human health and the environment during the construction and implementation phase.

- Reliability and proven effectiveness of the technologies with respect to the COCs under site-specific conditions.

Implementability is a measure of both technical and administrative feasibility of implementing a technology process. Initial technology screening eliminates technologies that are clearly ineffective or unusable at the site. Implementability aspects include:

- Technical feasibility that may include constructability or workability under site conditions, being able to operate and maintain to meet the PRGs, and the complexity of the technology.

- Administrative feasibility that may include permitting, and accessibility (easements, rights-of-way required; access to the properties to be addressed; and ability to impose ICs).

- Availability of services and materials which may include availability of special equipment, materials and specially trained and skilled workers required, and offsite treatment and disposal capacity.

Cost (capital and operation and maintenance costs) is a measure of resources that are required in technology implementation. The costs used in this document were obtained from published resources and previous projects. Cost evaluation at the technology screening phase is relative, typically presented as high, low, or medium compared to other technologies within the same technology type. The technologies with high cost but low protection of human health and environment are not considered for further evaluation.

5.2.2 Technology Screening Summary

Table 5-1 presents the rationales for technologies retained or eliminated based on the three preliminary criteria. The soil technologies and process options retained for further evaluation include NFA, ICs, excavation, containment and disposal. Based on the site conditions, no treatment technologies have been retained as soil alternatives.

5.2.2.1 NFA (Retained)

NFA has been retained in accordance with the requirements of Subpart F of the NCP as a baseline for comparison with the other technologies.

5.2.2.2 Land Use Controls (Retained)

Land use controls (LUCs) are administrative measures developed to protect human health and safety from the presence of hazards. LUCs are measures that limit access or use of a property to protect people from site hazards or provide warnings of a potential site hazard. LUCs include engineering controls and physical barriers (e.g., fencing), educational programs (e.g., public notification of residual concerns), and administrative and legal controls (e.g., zoning restrictions and easements) that help to minimize the potential for human exposure. They have been retained for alternative development.

LUCs would be effective for reducing the potential exposure to the site soil. LUCs are implementable and costs are low, therefore, LUCs are retained.

5.2.2.3 Excavation (Retained)

Excavation can involve removal of all impacted soil and "hot spots" from a site. Excavation is a well-proven and effective method for removing impacted materials from a site to prevent direct contact and exposure to the contaminants. Therefore, it will address the relevant remedial objectives for the site. Excavation is a mature technology and easy to be implemented. Cost for excavation is low compared to other technologies. Therefore, this technology is retained for further consideration.

5.2.2.4 In Situ Treatments (Not Retained)

In situ treatment technologies treat contaminants in place. Compared to *ex situ* treatment technologies, *in situ* remedial technologies handle contaminated media in place, therefore its process of handling hazardous materials potential is low, as well as disposal costs and exposure of the contaminants to the workers.

<u>*In Situ* Solidification/Stabilization</u>

In situ solidification/stabilization processes involve adding and mixing reagents with soil to trap, treat, or immobilize contaminants. This technology is typically implemented by grouting or using a large-diameter auger or other equipment to mix with soil while adding reagents. Treated soil will become stabilized to prevent contaminants from leaching out to groundwater. Types of solidifying/stabilizing reagents include Portland cement, fly ash, blast furnace slag, bentonite, organoclay, and powdered activated carbon. Note that *ex situ* solidification/stabilization is discussed separately under *Ex Situ* Treatment section.

In situ solidification/stabilization can be effect in stabilizing the contaminated soil and reducing contaminant migration vertically and horizontally. Overall this technology will reduce the site risks and protect human health and environment. A treatability study is required prior to a full scale implementation to develop mixtures of reagents. However, the site contaminated soil is non-hazardous and is a low-level threat (not a principal threat waste) to the environment, *in situ* solidification/stabilization, or any other treatment technologies, therefore would not be cost effective compared to non-treatment technologies. In addition, ICs are required to protect the treated areas from intrusive activities, i.e., excavation, drilling and injections, which may limit future site use and development. Cost of *in situ* solidification/stabilization is high compared to other technologies. Therefore, this technology is not retained because of the high cost and waste still remaining in place at the site.

Phytoremediation

Phytoremediation is a process that uses plants to remove, transfer, stabilize and destroy contaminants in soil. There are six general approaches to phytoremediation: phytoaccumulation, phytodegradation, phytostabilization, phytovolatilization, rhizodegradation, and rhizofiltration (Interstate Technology and Regulatory Cooperation Work Group [ITRC] 1999). A variety of plants have shown limited uptake of metals and BAP in surface soil. A pilot treatability study is necessary to develop ideal environmental conditions for plant growth and remediation before a full-scale implementation. Although it is relatively easy to implement, the effectiveness of phytoremediation may not be reliable and highly relies on plant types, seasonal temperature change, soil type, pH, and moisture content. In addition, phytoremediation may require an extended time period compared to several other technologies. Cost of phytoremediation is low to medium depending on needs for long-term maintenance, replanting, and monitoring. Therefore, due to unreliability and uncertainty in effectiveness this technology will be not be retained for further consideration.

5.2.2.5 Ex Situ Treatments (Not Retained)

Ex situ treatment involves the excavation and subsequent treatment of soil. The treated soil is either used as backfill within the site or taken offsite for final disposal depending on the final results of the treatment.

Landfarming

Landfarming is a bioremediation technology in which excavated soils are placed in land treatment units (LTUs) and mixed and tilled periodically to blend nutrients/amendments and water to enhance the biological activity within the LTUs. The LTUs are constructed with an impermeable liner i.e., compacted clay or high density polyethylene (HDPE) geomembrane, to protect the soil underneath the treatment area. Sprinkler systems are required for most of the cases to provide irrigation for the system (FRTR, 1997).

Landfarming typically is applicable for treatment of lighter petroleum compounds and it becomes less effective for the PAHs with more aromatic rings, i.e., BAP. It is not certain with current data available if landfarming is effective for lead in soil. In addition, landfarming is easy to implement but it may require a long period of time for microorganisms to degrade or stabilize the soil COCs, although the cost is low. Therefore landfarming is eliminated from further evaluation.

Ex Situ Solidification/Stabilization

Ex situ solidification/stabilization involves excavating and mixing contaminated materials with reagents to stabilize contaminants. The *ex situ* process is typically applicable to hazardous wastes to reduce the leaching potential and remove their hazardous/toxic characteristics before offsite disposal.

Ex situ solidification/stabilization is effective for lead in soil and is implementable, but the cost may be high. Based on the site data, the majority of the site soil is non-hazardous, which would not require treatment if disposed offsite. Therefore, this technology does not provide better benefits for the soil remediation compared to non-treatment technologies, therefore it is not considered for further evaluation.

Soil Washing

Soil washing is a process using a solution of leaching, surfactant, pH-adjustment or chelating agent to remove contaminants. The wash solution with washed COCs is treated by conventional wastewater treatment methods and treated soil can typically be reused onsite or sent offsite for non-hazardous disposal. This process can also be used to separate fines from coarse materials. The majority of contaminants are sorbed to the fines, and once separated the coarse materials could be reused.

Soil washing is effective method for separating metals from soil. It is implementable with commercially available equipment. However, the process is complex and produces a large amount of wastewater, which can increase the cost significantly. Therefore, it is not considered for further evaluation.

5.2.2.6 Offsite Disposal (Retained)

Disposal includes placement of waste materials in a permanent repository that is subsequently managed to prevent reintroduction of contaminants into the environment. Waste material and contaminated soil removed from the site must be disposed of at an appropriate waste management facility.

Offsite disposal is an effective process for permanently removing impacted soil. Regulatory requirements regarding waste characteristics for the disposed soil would dictate the type of landfill facility. It is implementable and cost is at an average level compared with other technology. This option adequately addresses the RAOs, therefore this process will be retained for further consideration.

5.2.2.7 Onsite Containment (Retained)

Containment technologies control human and/or ecological exposure to COCs by preventing the migration of COCs and/or preventing direct contact with impacted media. Onsite containment includes consolidation and placement of impacted soil under a protective cover or into a containment repository constructed onsite to prevent exposure and minimize the potential migration of COCs.

An onsite containment will address the relevant remedial objectives. It is implementable but it will require ICs to protect the integrity of the repository.

6. DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section presents the remedial alternatives that were retained for the site soil during the technology screening. The technologies retained were assembled to develop a range of alternatives and provide flexibility in selecting preferred alternatives. The development of the alternatives was based on the EPA's document, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), which advises to include:

- Alternatives that permanently reduce the toxicity, mobility, or volume of contaminants. The range of alternatives should, if possible, vary in the degree of reliance on long-term management of untreated wastes

- Permanent solutions to the maximum extent practicable

- Innovative treatment technologies and resource recovery technologies to maximum extent practicable

- One or more containment alternatives that involve little or no treatment of hazardous contaminants

- A "No Action" alternative.

The following remedial alternatives were identified as potential alternatives for the soil:

- Alternative S-1: NFA
- Alternative S-2: Soil excavation and offsite disposal
- Alternative S-3: Soil excavation and onsite containment repository
- Alternative S-4: Soil excavation, and onsite consolidation and capping

Table 6-1 presents a summary of the alternatives and RAOs that each alternative potentially could achieve.

6.1 COMMON COMPONENTS FOR SOIL ALTERNATIVES

ICs will be included as components in all of the soil alternatives with the exception of NFA. Land use in the mid and southern part of the Wilcox Process Area will be restricted to industrial and commercial use.

6.2 ALTERNATIVE S-1: NO FURTHER ACTION

Alternative S-1 assumes no remedial action for soil. It is used as a baseline for comparison to other remedial alternatives as required by the NCP. Under NFA, no remedial actions will be conducted at the site and contaminated soil posing unacceptable risks would be left in place.

6.3 ALTERNATIVE S-2: SOIL EXCAVATION AND OFFSITE DISPOSAL

Alternative S-2 includes excavation of soil exceeding the PRGs and disposal of the material offsite in a Resource Conservation and Recovery Act (RCRA) permitted and licensed landfill. Figures 2-5 and 2-6 show the locations of the soil exceeding the PRGs.

The main components of Alternative S-2 include:

- Pre-excavation delineation of contaminated soil exceeding the PRGs
- Site preparation including removal of vegetation in the excavation areas, setup of work zones, installation of erosion and sediment controls near the creek and associated tributaries if excavation nearby, and utility clearance.
- Excavation of the contaminated soil
- Transportation and disposal of the excavated material at an offsite disposal facility
- Backfill and restoration of excavated areas
- Implementation of ICs to restrict the land use.

A backhoe or excavator is generally used to perform the excavation. Excavated materials will be sampled for waste characterization for offsite disposal. The site will be backfilled with clean soil and vegetated. Sampling at bottom and side walls of the excavations will be conducted to confirm complete removal of the contaminated soil.

It is assumed for purposes of this FS the excavated soil will be characterized as non-hazardous waste based on historical data. Waste characterized as non-hazardous waste would be transported and disposed of at a RCRA Subtitle D Landfill. But if the excavated soil is hazardous, it will be transported and disposed of at a RCRA Subtitle C Landfill.

Alternative S-2 will meet the site RAOs by removal of the contamination offsite to prevent direct contact and prevent contaminants migrating to the groundwater and/or surface water. Since the material would be removed from the site, there would not be any post-remedial action maintenance or monitoring, except five year reviews, and the site would be available for assumed land uses.

6.4 ALTERNATIVE S-3: SOIL EXCAVATION AND ONSITE CONTAINMENT REPOSITORY

Alternative S-3 includes excavating the contaminated soil and consolidating and placing the excavated soil in a containment repository constructed onsite. A potential location of the containment repository can be in the mid-portion of the Wilcox Process Area, as showed in Figure 2-6, which is away from tributaries and drainage basins or creeks. The location of the containment repository will be determined during the remedial design and shall be in accordance with ODEQ solid waste rules and Oklahoma Administrative Code (OAC) 252 Chapter 515. The excavation of the contaminated soil in this alternative is the same as that in Alternative S-2. However, the excavated soil will be placed in an onsite containment repository, rather than being transported offsite for disposal. The containment repository will be constructed to meet the regulatory requirements for RCRA subtitle D landfill and OAC 252:515.

It is estimated that approximately 40,270 cys of soil would be excavated and placed in the repository. Therefore the repository could be assumed to be approximately 360 ft by 150 ft and 20 ft in height.

The main components of Alternative S-3 include:

- Same components from Alternative S-2 for soil excavation, backfill and restoration of the excavated areas.

- Site preparation of the containment repository area including removal of vegetation and setup of the boundaries of the repository based on containment repository design.

- Installation of bottom liner of the containment repository.

- Placement and compaction of the excavated soil in the containment repository.

- Installation of a low permeability cap.

- Implementation of ICs to restrict the land use to industrial and commercial in the containment repository area and prohibit any drilling and earth-moving activities at the repository area.

- Implementation of a groundwater program to monitor groundwater around the repository area in accordance with regulatory requirements.

A containment repository in general consists of, from bottom to the top:

- A bottom liner:
  - Compacted clay liner in 12-inch thickness with a hydraulic conductivity less than 1×10^{-7} centimeter per second (cm/s)
  - Geosynthetic clay liner
  - 60-milli-inch (mil) HDPE textured geomembrane
  - Composite drainage net
  - Protective cover.
- Excavated contaminated soil
- A cap:
  - A geosynthetic clay liner with a hydraulic conductivity less than 1×10^{-8} cm/s
  - A textured 60-mil low-density polyethylene geomembrane

- o A drainage layer constructed with composite drainage net
- o A protective soil cover at least 2.5 ft in thickness
- o A vegetation layer at least 6 inches in thickness.

A leachate collection system is assumed not necessary for the site soil under this alternative. Water in a containment repository may be generated from precipitation entering through the cap, and the initial moisture content of the soil itself. Physical, chemical, and biological processes of the soil compounds can also produce water and other compounds, but the water generated from these processes is small compared to precipitation and infiltration. Due to the impermeable cap of the containment repository, precipitation into the repository would be limited and reduced. Therefore the leachate generated from the repository is likely low. However, if this alternative is selected, design of the repository will need to include a water balance analysis to determine if a leachate collection system is required.

This alternative will address the RAOs by containing the contaminated material in the repository to prevent the direct exposure to the environment and leaching to the groundwater. However, the contaminated soil would remain at the site, thus ICs would be required to restrict the future land use and earth moving activities, which could potentially damage the repository. Groundwater will be monitored to confirm that the bottom liner prevents the contaminants in the repository from leaching to the groundwater.

6.5 ALTERNATIVE S-4: SOIL EXCAVATION AND ONSITE CONSOLIDATION AND CAPPING

Alternative S-4 includes excavating the contaminated soil and consolidating and capping it at the site. A potential location of the consolidation and capping can be the same as the location of the containment repository under Alternative S-3, as showed in Figure 2-6. The consolidation and capping location shall be selected in accordance with ODEQ solid waste rules and OAC 252 Chapter 515. The location will also be determined by its position away from the creek and residential areas, as well as its centrality. The excavation of the contaminated soil in this alternative is the same as that in Alternative S-2. However, the excavated soil will be placed in a location and capped, rather than being transported offsite for disposal.

The main components of Alternative S-4 include:

- Same components from Alternative S-2 for soil excavation, backfill and restoration of the excavated areas.

- Site preparation of the consolidation and capping area including removal of vegetation, and setup of work zones, staging areas, and the boundaries of the consolidation and capping.

- Placement and compaction of the excavated soil in the consolidation area.

- Installation of a low permeability cap, which would be the same as the cap under Alternative S-3.

- Implementation of ICs to restrict the land use to industrial and commercial in the capping area and prohibit any drilling and earth-moving activities at the capping area.

- Implementation of a groundwater program to monitor groundwater around the cap in accordance with regulatory requirements.

This alternative will address the RAOs by capping the contaminated soil to prevent the direct exposure to the environment, and minimize infiltration, therefore reducing leaching of the contaminants to the groundwater. However, the contaminated soil would remain at the site, thus ICs would be required to restrict the future land use and earth moving activities. Groundwater will be monitored to confirm that the capped contaminants are prevented from leaching to the groundwater.

7. EVALUATION OF REMEDIAL ALTERNATIVES

This section evaluates the remedial alternatives developed in the previous section following the EPA's RI/FS guidance (EPA 1988). The alternatives were evaluated against the seven of the nine criteria required in the NCP. Alternatives are compared, and key tradeoffs among them are identified to determine the most appropriate remedial actions for the site. The approach is designed to provide decision-makers with sufficient information to adequately compare the alternatives and provide the basis for selecting an appropriate site remedy pursuant to CERCLA requirements.

7.1 EVALUATION CRITERIA

The alternatives are evaluated in this section based on the nine criteria required by 40 CFR Section 300.430(e). The nine criteria used to evaluate each alternative are listed below:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Balancing Criteria

- Long-term effectiveness and permanence
- Reduction in toxicity, mobility, or volume through treatment (TMV)
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

- State acceptance
- Community acceptance.

The evaluation criteria are divided into three groups: threshold, balancing, and modifying criteria. The first two criteria as threshold criteria must be met by all alternatives in order to be eligible for selection as a remedial action. If ARARs are not met, six circumstances may be considered as listed in the NCP (see 40 CFR 300.430 (f)(1)(ii)(C)(1 to 6)), and a waiver may be obtained before an alternative is selected as a remedy. The next five criteria as balancing criteria are the primary criteria upon which the detailed analysis is based. Unlike the threshold criteria, the five balancing criteria weigh the tradeoffs between alternatives. A low ranking for one balancing criterion can be offset by a higher ranking on another balancing criteria. The last two criteria as modifying criteria are deferred until the public comment process and following receipt of feedback from the state and community. The nine criteria are described in the following subsections.

7.1.1 Threshold Criteria

To be eligible for selection, an alternative must meet the two threshold criterion or, in the case of ARARs, must justify why a waiver is appropriate.

- **Overall Protection of Human Health and the Environment.** A remedy is protective if it adequately eliminates, reduces, or controls all current and potential risks posed by the site through exposure pathways. Evaluation of protectiveness focuses on the reduction or elimination of site risks by the proposed remedial alternative.

- **Compliance with ARARs.** This criterion is used to evaluate whether each alternative will meet all of the federal and state ARARs or whether there is justification for waiving one or more ARARs. Table 4-1 identifies and presents ARARs for the site.

7.1.2 Balancing Criteria

There are five balancing criteria, described below.

- **Long-Term Effectiveness and Permanence.** This criterion is used to assess the residual risks at the site after RAOs have been met. The primary focus of this criterion is the extent and effectiveness of controls used to manage the risk posed by treatment residuals or untreated materials remaining at the site. The following factors will be considered under this criterion:

    - Adequacy and reliability of remedial controls to mitigate the remaining risks after the remedial activities

    - Magnitude of the residual risks after remedial activities.

- **Reduction of TMV through Treatment.** This evaluation criterion addresses the CERCLA statutory preference for treatment options that permanently and significantly reduce the TMV of the contaminants. The following factors will be considered under this criterion:

    - The amount of hazardous materials that will be destroyed or treated
    - The degree of reduction in TMV measured as a percentage of reduction
    - The degree to which the treatment will be irreversible
    - The type and quantity of treatment residuals that will remain following treatment.

- **Short-Term Effectiveness.** This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until the RAOs are met. Under this criterion, alternatives are evaluated for their effects on human health and the environment during implementation of the remedial action. The following factors will be considered:

- Exposure of the community during implementation
- Exposure of workers during construction
- Environmental impacts resulted from implementation and construction
- Time to achieve RAOs
- Sustainability.

- **Implementability.** This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials that may be required during its implementation. The following factors were considered:

  - Ability and difficulties to construct the technology
  - Ability to monitor effectiveness of the remedy
  - Availability of equipment and specialists
  - Availability of offsite treatment and disposal capacity and services
  - Ability to obtain approvals from regulatory agencies.

- **Cost.** Cost encompasses capital, operation and maintenance costs incurred over the life of the project. As stated in the EPA guidance (EPA 2000), cost estimates in the FS are expected to provide an accuracy of minus 30 percent to plus 50 percent (-30 percent to +50 percent). The estimated costs are designed to be used only for evaluating and comparing alternative technologies and not for setting budgets.

  The Remedial Action Cost Engineering and Requirements® (RACER) software, Version 11.4, was used to develop order-of-magnitude costs for this FS. RACER® is a parametric and integrated cost estimating program that was developed specifically for estimating costs associated with environmental investigation and remediation projects. It can be used at early order-of-magnitude stages of cost estimating. RACER® has been used by Department of Defense, Department of Energy, contractors, engineering consultants, state regulatory agencies and private sectors.

7.1.3 Modifying Criteria - State and Community Acceptance

State and community acceptance are the two modifying criteria. These two criteria evaluate the issues and concerns of the state and community regarding each alternative. These criteria cannot be evaluated until the state and community have reviewed and commented on the alternatives presented in the FS Report.

7.2 ALTERNATIVE EVALUATION

Evaluation of alternatives consists of the following two components:

- Evaluation of each alternative against seven of the nine evaluation criteria
- Comparative evaluation of alternatives relative to one another to identify key tradeoffs.

Table 7-1 presents the detailed evaluation of soil alternatives individually and following subsection presents comparative evaluation of the alternatives. The detailed evaluation confirms if alternatives achieve the threshold criteria, presents significant aspects and differentiators of the alternatives, and identifies uncertainties associated with the evaluation.

7.3 COMPARATIVE ANALYSIS

This section presents the comparison among the alternatives based on the detailed evaluation of each alternative. The comparison potentially identifies the most favorable alternative on each evaluation criterion. Table 7-2 provides a summary of comparative analysis for the soil alternatives.

7.3.1 Overall Protection of Human Health and Environment

All alternatives, except S-1 NFA, provide overall protection of human health and environment by removing the contaminants and containing the excavated soil either offsite or onsite, or capping the soil onsite to eliminate or reduce the site risks. Alternatives S-2, S-3 and S-4 include ICs to restrict land use to industrial and commercial only in the Wilcox Process Area. Alternatives S-3 and S-4 will also consist of additional ICs to protect the containment repository and cap, respectively.

Alternative S-2 ranks the most satisfactory among the three alternatives regarding protection of human health and environment because the contaminated materials would be removed permanently and disposed offsite in an approved landfill with limited human health and environment risk. Under Alternatives S-3 and S-4 however, more protection measures (i.e., ICs) would be used to maintain protection at the site.

7.3.2 Compliance with ARARs

Table 4-1 presents a compilation of the federal, state, and local ARARs identified for the site. Compliance with ARARs is not applicable to S-1, NFS. All other alternatives are anticipated to comply with ARARs.

7.3.3 Long-Term Effectiveness and Permanence

Alternative S-1 would not provide long-term effectiveness and permanence. Alternative S-2 would provide the best long-term effectiveness and permanence because all contaminated materials are removed and disposed offsite. Alternatives S-3 and S-4 would only provide long-term effectiveness and permanence if certain conditions are met. Since the contaminated materials would remain onsite, Alternatives S-3 and S-4 would require long-term monitoring and maintenance to protect the contaminated materials, eliminate direct exposure to all receptors, and prevent leaching into the groundwater.

7.3.4 Reduction of TMV through Treatment

All alternatives except Alternative S-1 reduce the mobility of the contaminated materials. None of the alternatives involve treatment, therefore a reduction in toxicity and volume of contaminated soil is not expected.

7.3.5 Short-Term Effectiveness

All alternatives, except Alternative S-1, pose short-term impacts during implementation of the alternatives on workers, communities, and the environment; however, the impacts are low. Proper personal protective equipment and best practice management will be used to alleviate the impacts. Alternative S-3 would require the longest time to implement due to the construction of the containment repository. The transportation of waste offsite in Alternative S-2 would present the greatest short-term risk to the community.

7.3.6 Implementability

All alternatives except S-1 involve mature technologies and typical construction methods and equipment. Thus, they are readily implementable. However, Alternatives S-3 and S-4 involve more processes and technologies than Alternative S-2. Constructing a containment repository or a cap under Alternatives S-3 and S-4, respectively, would require more materials compared to Alternative S-2, and would involve a quality control and quality assurance program to ensure the liners or cap are constructed in accordance with the design. Therefore, Alternative S-2 ranks the most satisfactory regarding implementability, followed by Alternative S-4, then Alternative S-3.

7.3.7 Cost

Table 7-1 presents the cost of the alternatives for soil. Appendix D provides the detailed cost estimates. Overall, Alternative S-3 is highest in 30-year net present value among the alternatives.

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Tables

Figures

Appendix A

Responses to Comments on FS Report, Revision 00

Appendix B

Technical Memorandum on Data Gap Investigation

Appendix C

Development of Human Health Risk Based Preliminary Remediation Goals Technical Memorandum

Development of Ecological Preliminary Remediation Goals Technical Memorandum

Appendix D

Detailed Cost Estimates